Finding Efficiencies of the LBCF in the Soudan Underground Lab

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Goals

To determine the efficiency of the LBCF (Low Background Counting Facility) Veto Shield in counting muons in order to ensure and improve data quality.

Background

In the Soudan Underground Mine there are several physics experiments currently running, including MINOS, CDMS, and Cogent. The uniting theme in all of these experiments is the fact that they are looking for rare, unique events, which must be differentiated from the noise. That is where the LBCF Veto Shield (Fig 1) comes in. It was originally installed for the Proton Decay experiment which started in 1989 (Soudan 2). The shield has been revived from disuse after Soudan 2 was removed to begin studying the properties of the muons that enter the mine and the potential for them to produce neutrons in the surrounding rock. A Neutron Multiplicity Meter (Fig 2) was also installed to detect neutrons as well as muons.

Fig 1 – A view of the shield from the northwest corner on a platform

In order to better understand the data we are taking and eventually modify the hardware and settings to optimize muon efficiencies, a Geant4 simulation coupled with the MUSUN muon generator was used to simulate the paths of muons through the shield.

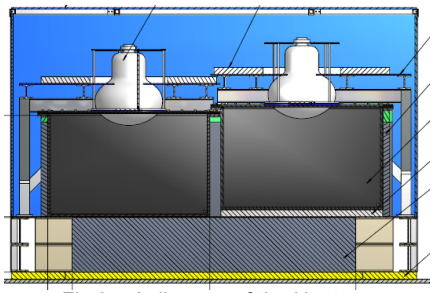

Fig 2 – A diagram of the Neutron Multiplicity Meter located within the shield

Technique

Using the output files which recorded the tracks, MatLab was used to find out how many muons that went through the shield would have been detected by our data collection system. To do this, first, one must modify the data that was given by the simulation and derive a few other data points. Knowing that if a particle were to produce an electron in the process of going through the detector, it would register as a separate step, therefore, any event in a single detector could be combined. Then for each unique event, the corresponding channel in our electronics was found. To do this, an database on our SQL Server was indexed for MatLab to quickly query in order to find which detector corresponds to which channel. This was necessary to have a realistic triggering algorithm that accurately reflected the shield electronics.

Fig 3 – The northeast portion of the data acquisition system

Once the data was prepped, counting triggers became mostly a task of implementing the algorithm already running on our data acquisition equipment (Fig 3). These triggering requirements, which are one of the things we are looking to optimize through this study, consist of an energy threshold (by way of the physics of the tubes), the latch, and the trigger conditions. Essentially an event qualifies as a trigger-able event if one channel in a given tube registers a signal and either the opposite channel registers on an adjacent tube or the opposite channel in the same tube register a signal within 1.2 microseconds (example in Fig 4).

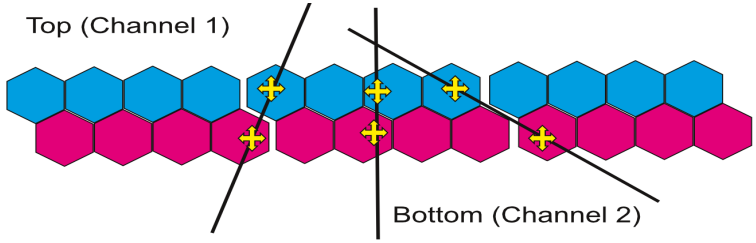

Fig 4 – A diagram of several sample triggers in the configuration the tubes are arranged in. The lines represent paths of muons, the

References

Villano, A. (2014, April). *Veto-Shield Geant4 Simulation*. Retrieved from http://goo.gl/bnl4l0

Stifter, K. (2013). *Correlating Neutron Multiplicity Meter and LBCF Muon Data*. Retrieved from http://conservancy.umn.edu/handle/11299/158290

Findings & Accomplishments

Using this information, the efficiency of our data acquisition system and the shield overall was found. The estimated efficiency is about 94.34%, in other words, of the total amount of muons that enter the cavern, about 94.34% of muons will register and be recorded by our electronics. This information, and more importantly, the method developed for finding this information will be used to determine and evaluate ways to improve the efficiency of the veto shield.

During the course of the semester, another undergrad and myself also did work on two primary hardware projects. First we set up the beginning of a muon telescope in the new PAN building. Over spring break, we went up to the Soudan lab and spent two days laying cables for a new high voltage supply that will be fully implemented this summer (Fig 5).

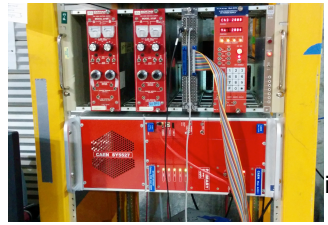

Fig 5 – The old power supplies (top) above the new one

Further Work

Work on extracting more data from the existing simulation will continue. This includes analysis of the optimal voltage to run the detectors at. This will happen in parallel with ongoing improvements to the simulation. We will also finish the implementation of the new high voltage system, and work on the muon telescope.

Acknowledgements

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